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FERMENTATION OF AGRO–BASED WASTE AND RESIDUES FROM DIFFERENT SECTORS: A REVIEW

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ABSTRACT

In India the economic importance of food and food processing sector is dominating. But the environmental issues like wastes or by-products of food industry sector is an alarming problem today. In food processing and packaging industry about one third of the food is spoilt before it reaches the consumers. This shows a huge economic loss in food sector. There are certain methods of dumping into the ground, incineration of agricultural waste and using the ash in agricultural lands. But this methods causes environmental degradation and polluting the environment. Dumping the agro-waste under normal ground causes decomposition and foul smell. Again the incineration if carried out without proper technique causes pollution. Hence, degrading the environment. So, one of the major scientific technique is carrying out different type of fermentation processes such as solid state fermentation and submerged state fermentation which could be helpful to convert this wastage into some useful high value products with the help of living cells or microorganisms in a controlled optimal atmosphere inside a specially designed suitable bioreactor or fermenter and following a suitable recovery process the final product is recovered and purified.

KEYWORDS: Fermentation, Agro-Wastes, Solid State Fermentation, Liquid State Fermentation, Substrates, Microorganisms

Review Article

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INTRODUCTION

Food processing and packaging sector contributes to a huge agricultural wastage. These wastes causes different pollution problems on disposal in the ground and a huge loss of valuable biomass and nutrients is observed. Different sectors included in food industry is fruits and vegetables processing, oil seed, sugar, milk and milk products, tannery, textile and packaging industries. From these sectors during many unit operation processes a huge loss of nutrient is there in form of solid wastes like fruit peels, seeds, skin, bran, hey, whey, wood and paper pulp, fish gills, scales and liquid wastes as sugar syrups, molasses, fruit juice are wasted. (Pandey *et al*.1999). Food wastes from the food processing industry contains many nutrients in form of carbohydrates, proteins, lipids, suspended particles according to the high bio-chemical oxygen demand and chemical oxygen demand (Jayathilakan 2012) which is used by the microorganisms in the fermenter as their nutrients to grow and carry on the multiplication and fermentation process.

Concept of Fermentation

The basic concept of fermentation is to facilitate the rapid escalation, multiplication and growth of the target organisms in the nutrients provided as substrates. The desirable microorganisms metabolises the present

sugar in the substrate into chemicals like ethanol (alcohol), lactic acids. (Hui *et al.* 2004). Enzymes are protein which is synthesized as intra and extra cellular compounds. Enzymes energize and catalyze biochemical reaction with high specificity and enhance the reaction rate (Renge *et al*. 2012).

Type of Fermentation

Depending on the state of substrate the fermentation can be classified into Solid state fermentation and Liquid or submerged fermentation. In solid state fermentation the solid wastes which can be easily recycled can be directly used as substrate as high nutrient medium for growth of target microorganism. Whereas in liquid fermentation the free flowing liquid wastes from processing industries like molasses and broths are used as the nutrient medium. The solid substrates has an advantage that it can be used slowly and steadily upto a long period of time by the organisms, while the liquid substrates get easily and rapidly used up hence time to time supplementation of nutrient is required which is time consuming. While the solid state fermentation is carried out where the target organism needs less moisture content such as fungi, the liquid fermentation is suitable for high moisture activity microorganisms like bacteria. But the liquid fermentation gives advantage of easy purification and recovery after the fermentation process and is used where the product is needed in liquid form. (Subramaniyam and Vimal 2012).Each type of fermentation has its own advantages.

The selection of substrate for the fermentation depends on many factors such as the nature of target organism, the nature of product to be generated. Cost and availability of the substrate also plays an important role as for high volume, low cost product the substrate should not be plentyly available in low cost. Particle size should also be considered, the smaller particle size gives a good surface area for the proliferation of the target microorganisms but if the size is too small then proper enzyme action cannot occur hence resulting in poor growth of the organism resulting to incomplete fermentation and less product formation. Likewise large size particles doesn’t give more surface area, though aeration and respiration is accelerated in this case. (Suganthi *et al*. 2011).The moisture content of the substrate is also required as per the target organism. When the target oraganism is bacteria more moisture substrate is required than in case of fungi which require less moisture to grow. The product nature determines the selection of the substrate as well as the target microorganisms.

Factors Influencing Fermentation

Factors affecting fermentation includes a number of important parameter which are needed to be taken care of during the process. Temperature, pH level, level of dissolved oxygen and dissolved carbon dioxide inside the substrate, cooling of the vessel with cold water is maintained throughout the fermentation process. The chemical composition of the substrate (whether it is in solid or liquid/submerged state),type of operation(i.e. batch, fed-batch or continuous), type of feeding inlet, type of mixer or agitator blades, power of the agitator motor, shear rate are some other factors which are the factors which should be maintained else its variation leads to different problems affecting the quality and quantity of the product by affecting its taste, smell, appearance and texture. Sometimes different toxins are created which leads to difficulty in purification.

Bioactive Compounds Extracted

Various useful components are extracted by using different suitable fermentation method according to the waste substrates available. These components are of many commercial uses and have high economic values. Many bioactive compounds such as antibiotics (Maragkoudakis et al., 2009; Saykhedkar and Singhal, 2004; Ohno, 1995), pigments

(Dharmaraj et al., 2009), enzymes (Aguilar et al., 2008; Kokila and Mrudula 2010), hypercholestrolemic agents (Xie and Tang 2007; Pansuriya and Singhal, 2010), antioxidants (Tafulo et al., 2010), antihypertensive agents (Nakahara et al., 2010), antitumor agents (Ruiz-Sanchez et al., 2010), biosurfactants and bioactive peptides (Pritchard et al., 2010) have been extracted using fermentation.

Fermenter

A fermenter also known as bioreactor is generally used in a vast field of biochemical and pharmaceutical industry. A fermenter is a specially designed vessel or container made of stainless steel, glass or non-corrosive material in which residues and wastes from different agricultural sector such as peels, seeds, outer covering of fruits and vegetables, fish wastes such as gills, scales which are rich in protein, paper and wood pieces, sugar molasses and bagasses etc are converted into products of some use. The optimum temperature, pH and other suitable environment is created, maintained and controlled inside the reactor by different devices so that to encourage the growth of required specific microorganisms. All bioreactors have heterogeneous systems which deal with two or more phases like solid, liquid and gas. Sterilisation of the substrate and the bioreactor is yet another important factor which is needed to be taken care of so as to stop the growth of unwanted microorganisms other than the required ones. In a fermenter the low value waste substrates are converted and used into high value products by utilising living microorganisms or enzymes.

Fermenters are of different capacities depending on various factors. The design and capacities depends on the specific target microorganism, the optimal temperature, pH and other optimal parameters required for the growth of the target microorganisms and the quantity and quality of product. Another factor is the monetary investment and cost of running and maintenance. Bioreactors or fermenters can vary from shake conical flask (100-1000 ml), in laboratory the fermenter ranges from (1-50 L) or more, for pilot scale level (0.3- 10 m^3) to plant scale (2-500 m^3) depending on quality and quantity of the high value product. For products like alcoholic beverages, and lactic acids production an simple running fermenter is required without much asceptic conditions maintenance as the recovered product is of large volume and low value. For high value and low volume products such as single cell protein, antibiotics more asceptic condition is maintained and more systematic operation is required (Jagani et al.2010).The diagram of a fermenter showing different components is shown in the figure 1.

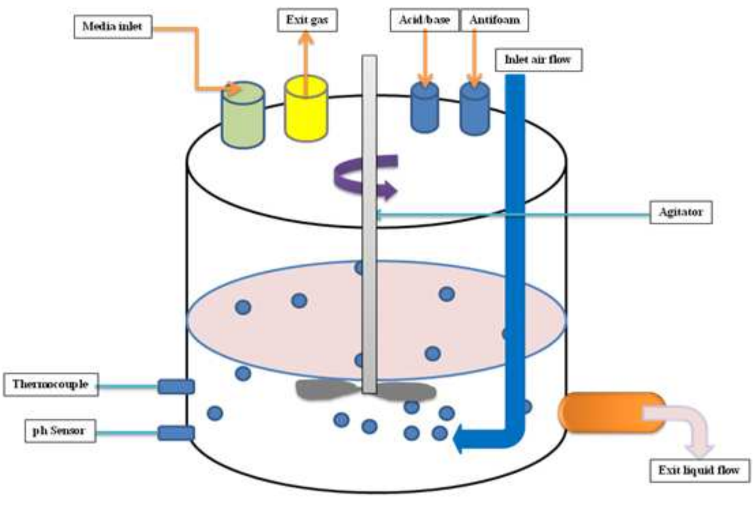

Figure 1: Diagram of a Fermentor Showing Different Basic Component

Substrates and Products from Different Agricultural Sectors Waste Products

Table 1: Different Wastes and Fermented Products Obtained

Wastes	Microorganisms	Products	References
Substrates from Fruit and Vegetable Processing Wastes			
Wheat Bran	*Bacillus coagulans* *Cellumonas sp.*	α- amylase	Paula Monteiro de Souza *et al.(*2010)
Banana Fruit stalk	*Bacillus subtilis*	α- amylase	Paula Monteiro de Souza *et al.(*2010)
Rice Polish Wastes	*Penicillium notatum*	Glucose oxidase	S. Sabir *et al*.(2007)
Grape skin pulp extract, Olive oil waste effluents, Coconut milk	*Aureobasidium pullulans*	Pullulans(manufacture of edible films that are used in various breath freshener or oral hygeine & food additive products)	Thirumavalavan, K *et al*.(2009)
Fruit Pulp waste	*Saccharomyces cervisiae*	Ethanol (With this type of fermentation, least 4% and most 8-10% alcohol production is there)	H.S.Vishwakarma *et al*.(2014)
Peach waste	Baker's yeast *Saccharomyces cervisiae*	Drinkable alcohol can be obtained after application of graded distillation. Brandy which is distilled alcohol with peach aroma 6 litre brandy with 43% alcohol can be obtained from 100 kg peach waste.	Kuldip Gupta and V.K. Joshi(2000)
Apple pomace,	*Streptomyces fradiae*	Neomycin The highest neomycin production (2765 µg/g substrate) was achieved with apple pomace by SSF	BM Vastrad and SE Neelagund (2011)
Extracted grape waste material Pressed apple pulp rich in carbon	*Penicillium funiculosum* *Myrothecium verrucaria* *Aspergillus niger*	Cellulolytic enzymes, Single cell protein	Kuzmanova, S. *et al.* (1991)
Dry orange Peel	*Aspergillus niger* *Penicillium janthinellum* *Penicillium restrictum* *Trichoderma viride* *Mucor pirifromis* *Botrytis* *Ascochyta* *Absidia* *Talaromyces* *Acremonium* *Eupenicillium*	Citric acid (193 mg CA/g dry orange peel)	Torrado *et al*.(2011)
Citrus fruits peel	*Aerobacter* *Bacillus polymyxa.* *Xanthomonas campestris*	2,3 butylyene glycol (monomer) further used in synthetic rubber production Xanthan	Sterling et al.(1967)
Primarily husk, cobs, and missed kernels(maize)	*Aspergillus niger* *Pycnoporus cinnabarinus*	Vanillic acid & Vanillin	Ong Khai Lun *et al*.(2014)
Substrates from Sugar Industry Wastes			
Molasses are source of carbon in fermentation	Saccharomyces Cervicae (yeast)	Ethanol L-lysine	Gasmalla *et al.* (2012)

processes	Corynebacterium glutamicum (for L-Lysine & L-glutamate)	L-glutamic acid.	
Effluents in sugar industry	*Candida utilis*	Single cell protein (SCP)	Rosma *et al.* (2006)
Cassava wastes	*Aureobasidium pullulans*	Exopolysachharide (Pullulans)	R.C. Ray and S.N. Moorthy (2007)
Cassava and sweet sorghum sugar Cane bagasse, sugar cane press Carrot-processing waste and starch	*Rhizopus oryzae* in SSF	Lactic Acid Yield of 137.0 g/l and the productivity of 1.43 g/l per hour	Soccol *et al.* (1994)
Cranberry pomace	*Lentidus edodes*	Ellagic acid	• Dhiraj A.V. and • K. Shetty (2003)
Production of by on untreated beet molasses in a loop airlift reactor	*Acetobacter xylinum*	Bacterial cellulose	Handbook of waste management
Cassava bagasse hydrolysate	*Rhizopus formosa*	Fumaric acid best producer, yielding 21.28 g/L	Handbook of waste management
Potato waste Cassava wastes Other starch rich vegetables	*Saccharomyces cervisiae*	Bio-ethanol yield (87% of theoretical maximum) 29–36mL alcohol/100g of sun-dried cassava starch	Handbook of waste management
Potato steam peels	Photo-heterotrophic fermentation Cyano bacteria, purple bacteria	Bio-hydrogen which is a very high energy (122 kJ/g) yielding fuel	De vrije and Claassen (2003)
Maltodextrins result from enzymatic or acid hydrolysis of starch wastes	Filamentous fungus *Penicilium notatum* *Cephalosporium*	Penicillin, Cephalosporin, Streptomycin	Geovana *et al.*(2005)
Corn steep liquor is a fermented by-product of the corn wet-milling process; rich in minerals & amino acids, vitamins	*Saccharomyces cerevisiae*	Penicillin G, Amino acids, Enzymes, Bio pesticides.	Handbook of waste management
Substrates from Milk Industry Wastes			
Sugar is broken down, and lactic acid is produced as a by-product.	*Streptococcus thermophiles,* *Lactobacillus acidophilis*	Lactic acid fermentation (Yoghurt) in milk gives Casein	Yantyati *et al.* (2014)
Molasses supplemented with whey as a broth and fermentation	*Candida curvata* yeast	Microbial fat	Yantyati *et al.* (2014)
Substrates from Textile Sectors Wastes			
Paper, textiles, canvas and cotton wastes	*Myrothecium verrucaria*	Cellulase	Mahalaxmi M. *et al* (2011)
Cotton Textile Mills generate about 85,000 T of solid cellulosic wastes popularly known as Willow-dust and cyclone dust.	Methanogens *Eg: Methanococcus,* *Methanothrix*	Biogas By methane formation Raw material: 100 tonnes Total gas generation : 100 cubic m	-----

Substrates from Oil Industry Wastes			
Plant lipids and oils cakes	*Penicillium* & other fungus by SSF	Bulk antibiotics such as: ▪ β-lactam group (penicillins and cephalosporins), ▪ Tetracyclines, ▪ Macrolides ▪ Antifungal polyenes.	A. Paithankar and A. Rewatkar (2014)
Oil Cakes Rapeseed palm peanut sesame soy oil cakes	*Pichia stipitis, Saccharomyces cerevisiae*	Bio-ethanol used for the trans-esterification of vegetable oils to produce mono ethyl esters of fatty acids as biodiesel	A. Paithankar and A. Rewatkar (2014)
Substrates from Tannery Wastes			
Animal fleshing, the major proteinaceous solid waste generated from leather industry	*Bacillus cereus 1173900* by SSF	Alkaline protease Maximum protease activity of 12,310 U/g was observed at 60 h in SSF crude extract. (U) = 1 µmol min^{-1}	Ravindran *et al.* (2011)
Bio- effluent	*Bacillus subtilis*	Extracellular alkaline protease	
Sulphite waste liquor, side product of the paper pulp manufacturing,is rich in pentose-sugars	*Candida yeasts* *Bacillus licheniformis,* *Bacillus stearothermophilus*	Ethanol α- amylase	Paula Monteiro de Souza *et al.*(2010)
Substrates from Fish & Fishery Wastes			
Fish Gills, Shrimp wastes	*Corynebacterium glutamicum.*	L-lysine (amino acid)	Xu J *et al.*(2014)
Fish wastes, mixed with 5% (w/w) sugar beet molasses	*Lactobacillus plantarum*	Fish silage excellent protein source having high biological properties for animal feeding.	Ghaly et al.(2013)
Composted fish waste	*Scytalidium aciabphilum* by SmF	Good protein yield for animal feeding.	Ghaly et al.(2013)

Recovery & Purification of Fermented Products

Desired products are separated and purified after successful fermentation or enzyme reactions Investment in recovery equipment is high. Isolation costs represent a good proportion (sometimes up to 60%) of the cost of the final product. In one antibiotic factory, recovery equipment cost four times more than the fermenter. The necessity of having a well-planned and reliable recovery process and an efficient recovery plant is therefore of utmost importance.

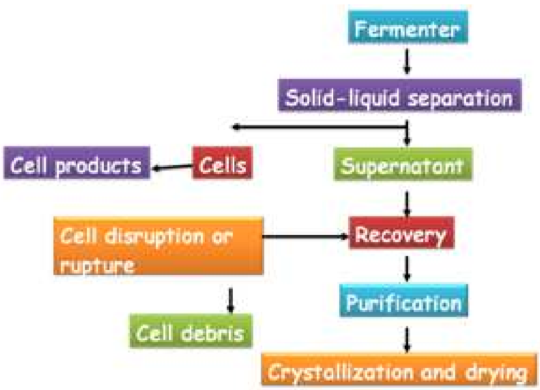

Figure 2: Flowchart for Recovery and Purification of Fermented Products

CONCLUSIONS

The food industry witness a huge loss of the products in form of peels, crushes, seeds etc during different processing and packaging processes. The food waste products are must be utilised. Fermentation is process involving microbial growths, which is widely accepted in bio chemical and pharmaceutical industry is now used in the food industry to ferment the by-products of the food industry as the substrates to carry the growth of required microorganisms into mane useful products like acids, alcohols, antibiotics etc. These products are commercially useful and add to the economy of food industry.

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